24.1: Fingerprint Scanner Using a-Si: H TFT-Array

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Abstract

Two-dimensional contact type fingerprint scanner with a resolution of 300 dpi (84 μm dot pitch) were fabricated for the fingerprint recognition. This sensor array consists of three parts; a sensor thin film transistor (TFT), storage capacitor and switch TFT. High quality of captured fingerprint image was obtained through the a-Si:H TFT-array with a high photo to dark current ratio of above 3 order of sensor TFT.

Introduction

Recently, as the rapid growth of electronic commerce, electronic transactions (on-line banking), IT security and physical access has created, the interest on security has been increased for user identification and authentication. Biometrics is the automated personal identification system using unique human characteristics such as fingerprint, voice, face, hand, retina or iris has emerged as the reliable security equipment. And the demand for biometrics will be driven by the growth of electronic commerce and intranets, and sales will be boosted by shrinking product size and greater awareness. From the cost, ease of use, and accuracy point of view, the fingerprint recognition security has been developed to verify identity as a leading alternative to conventional passwords and keys. Optical sensors are the most common method of fingerprint identification, but have still some problems such as high cost, bulky and image distortion[1]. Recently, the silicon chip-based sensors have been developed and proposed because they can be made very small and inexpensive. However, they are prone to electrostatic breakdown and likely to be damaged by the environment condition.[2]

[illegible] contact type image sensors using the photoconductivity of a-Si:H layer have been investigated by some researchers for the application of facsimile, scanner and the like equipment.[3-5] Thus, various structures have been proposed to increase the photoconductivity of the sensor TFT with relatively thin photo-receiving layer of a-Si:H. However their resolutions of TFT-array were relatively low and their structures were not suitable for the fingerprint recognition.

In this work, two-dimensional contact type fingerprint scanner with a resolution of 300 dpi (84 μm dot pitch) was fabricated using an a-Si:H TFT-array. The performance and photo-conductivity for the sensor TFTs with a new structure have been studied and published.[6] Captured fingerprint image was obtained by sensor module (called 'FingerTalk').

Fabrication of a-Si:H TFT array

Figure 1 shows a cross sectional view of the sensor array fabricated in this work. The sensor TFT and switch TFT were designed as a back channel-etched (BCE) a-Si:H TFT. The fabrication process of this fingerprint sensor is completely compatible with that of conventional a-Si:H TFT-array process in active matrix liquid crystal displays (AMLCDs). The storage capacitance of 1pF and light-passing window of 80% through the storage capacitor were designed to improve its signal-to-noise ratio (S/N) and to increase the photocurrent of sensor TFT, respectively. The gate electrode of Mo and the capacitor electrode of ITO were patterned on the glass substrate. The 2000 Å-thick silicon-nitride (SiN_x), 3400 Å-thick a-Si:H and P-doped (n^+) a-Si:H were successively deposited by plasma enhanced chemical vapor deposition (PECVD) method. The n^+ a-Si:H layer in the TFT channel region has to be etched off using the source/drain pattern as a mask after these electrodes are formed for both sensor and switch TFTs. Then SiN_x and Mo were deposited on the TFT-array and the Mo layer on the switch TFT was patterned as a light shield layer that prevents direct photo-exposure of the channel region. Finally, the passivation layer (SiN_x) was prepared to protect the sensing array against environmental contaminants.

The red color light-emitting diode (LED) was used as a backlight. It has been well known that the spectral response of a-Si:H covers the entire visible spectrum and peaks at a wavelength of about 590 nm.[7,8] The channel ratio of width to length of the sensor TFT and switch TFT for the FingerTalk were 18 μm/5 μm and 48 μm/5 μm, respectively.

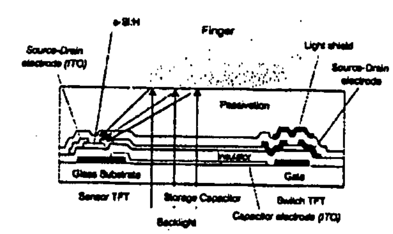

Figure 1. A cross sectional view of the sensor array with 300 dpi

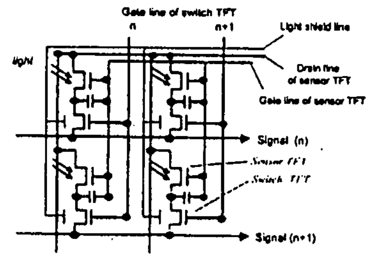

Figure 2. An equivalent circuit diagram of the sensor Array for 4 dots

Results and Discussion

Figure 2 shows an equivalent circuit diagram of the sensor array for 4 dots. The photocurrent was generated by the sensor TFT with the reflected light and then was charged at the storage capacitor during the frame time. The information signal of the fingerprint pattern, the photo-generated charge, was transferred to the readout circuits during the predetermined gate pulse time of the switch TFT. The output signal could be achieved by signal amplification and noise cancellation. In a-Si:H TFT-array, the dc voltages of –5V and 10V for the sensor TFT were applied to the gate and drain electrodes, respectively. The lower electrode of storage capacitor connected to the gate electrode of sensor TFT. The shield line is biased to the ground potential, V_{sh} (0V) and acts to prevent the electrostatic damage from fingers. The gate pulse voltage of switch TFT changes from –5V (off) to +15V (on) during the readout of line signal.

Figure 3 shows transfer characteristics (I_d-V_g) of the sensor TFT at the drain voltage of 10V. The channel ratio of width to length of the sensor TFT was 10 μm/8 μm. The photocurrent I_{ph} is given by

[illegible] ..... (1)

where α is the absorption coefficient of a-Si:H and t is the thickness of the film. Therefore, a thicker a-Si:H film is preferable in order to increase the photocurrent in the BCE type of TFT. However, the thickness of a-Si:H as a active layer is limited to get a good performance of switch TFT.

In addition, the photocurrent in the photoresistor is given by

$$I_{ph} = qFG \quad ..... (2)$$

Where q is the electron charge, F is the total number of free charge carriers generated per second in the photoconductor under illumination, and G is the photoconductive gain.

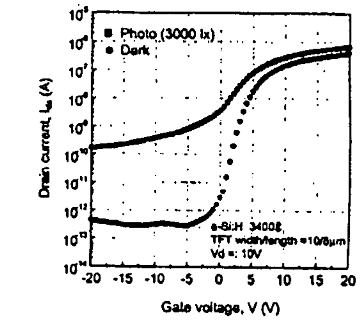

Figure 3. Transfer characteristics of the sensor TFT at the drain voltage of 10V

In this work, the source/drain electrode of the sensor TFT was formed with a transparent electrode (ITO) to increase the optical aperture. Thus, the sensor TFT has a large photo-receiving layer structure schematically. The photocurrent under top illumination increased up to nA level of drain current of TFT in the negative gate voltage. The photo to dark current ratio of above 10^3 was obtained with 3000 lx illumination at the gate voltage of –5V. The shadow region in the figure 3 corresponds to the actual operation zone of the sensor TFT for a fingerprint pattern.

Figure 4 shows an equivalent circuit of the sensor array and readout amplifier. In general, image sensors consist of photosensitive elements that convert the incoming light to electric charge and of the means for reading out this light-induced charge. In an array with a total number of N elements scanned with a frequency f, each element in the array is then periodically addressed for $\Delta t = 1/f$ seconds every $N\Delta t$ seconds. Each channel consists of a low noise charge integrator, sample-and-hold [illegible] scanning rate of 256 readout channels is 1 MHz. The readout time for each line is 0.256 ms. The gate pulse width and one frame time are 50 μs and 83.3 ms, respectively. The signal charge from the sensor TFT is transferred via the on-resistance (R_{on}) of the switch TFT to the readout capacitance with the time constant. And then the voltage at the end changes due to the parasitic capacitance C_p (30 pF) of the readout line. Thus, the simulated readout signal of in order of 200 mV was obtained by computer simulation.

Figure 5 shows the first captured fingerprint image by the prototype 'FingerTalk'. The performance of FingerTalk has real time image (12 frame/sec, 8bit depth) although there are some defects such as line open and point defects in fingerprint images. A clearing image is very important to extract a reliable minutia template of fingerprint.

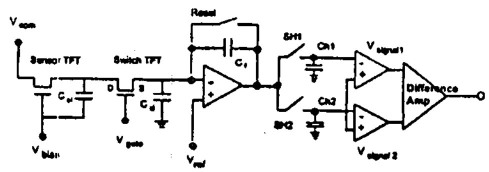

Figure 4. Equivalent circuit of the sensing array and readout amplifier

The specifications for the FingerTalk are shown in Table 1. A 1.2-inch-diagonal sensor array with the resolution of 300 dpi was designed for the verification. The size of the sensing area on the glass surface could be more flexible for a wide range of existing and future applications. FingerTalk solution is less expensive, smaller, more reliable and accurate than existing readers. In addition, this device is none of the image distortion induced by complex optical light path of conventional optical device. So, each sensor is identical to all others.

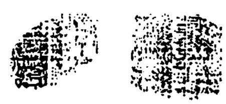

Figure 5. 1" captured fingerprint image

Table 1. Specification of FingerTalk with 300 dpi

ITEM	Specification
Device structure	a-Si TFT
Dimension (mm)	TBD
[illegible]	[illegible]
[illegible]	300dpi
Number of Gate pad	240
Number of Data pad	256
Storage capacitor	1pF
Switch TFT's R_{on}	< 5MΩ (Vg=12V)
Switch TFT's Off current	$< 10^{-11}$ A
Sensor TFT photo current	$> 10^{-10}$ A (Vd=10V)
Sensor TFT Off current	$< 5\times10^{-13}$ A
Gate input voltage	-7 ~ +15 V
Data output voltage	0 ~ 200 mV
Shield voltage (V_{sh})	0 V
Common voltage	+10 ~ +12 V
BIAS voltage	-5 V

Conclusion

A fingerprint scanner 'FingerTalk' with 300 dpi was developed by using a-Si:H TFTs. Each dot in the TFT-array consists of three elements; a sensor TFT, storage capacitor and switch TFT. The transparent electrode, Indium-Tin-Oxide (ITO), was used as a source/drain electrode and capacitor electrode to improve the photosensitivity of sensor TFT.

The back-channel-etch TFT structure was used for both sensor and switch TFT. The thickness of a-Si:H was about 3000 Å. Good quality fingerprint images were achieved.

Acknowledgments

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